

Providing Reliable Spacecraft Power for the next 40 years

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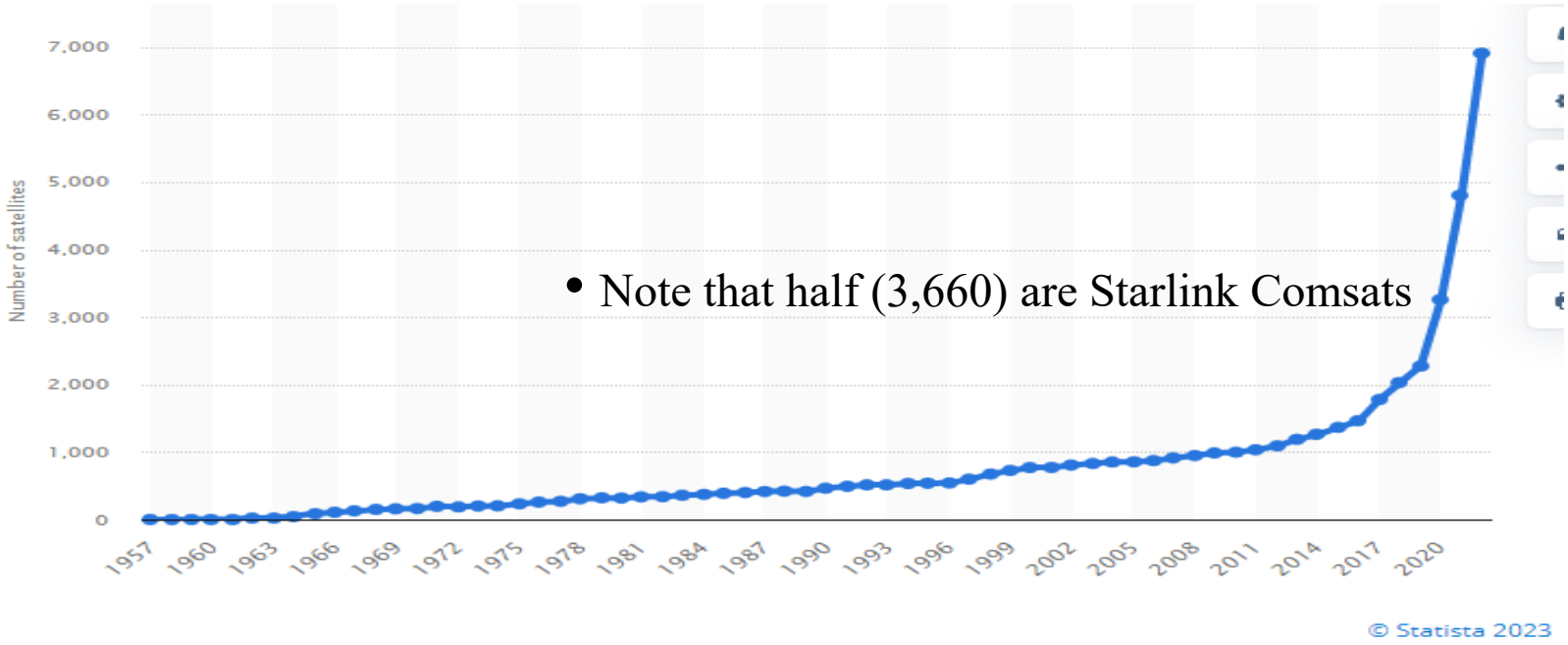
A historical Perspective

- Historically each satellite has been hand-crafted and built over 3-5 years.
- GPS Sats (2 launched/year) have been produced in four blocks of 20 since ‘78
- Comsats also were produced in batches (50 Hughes 376 spinners, 74 Boeing 601s)
- A new generation of service providers and sat makers with large fleets (mostly in LEO) has now increased the demand for modular, scalable, and mass-produced & tested Electrical Power Systems.



Fewer than 20 Sats per year were launched over the first 60 years of our space age

How do we accelerate the cycle of specification-to-launch while keeping reliability at acceptable levels?

- Power Processing blocks of known performance can be configured in parallel "channels" to allow scalability for higher power and/or reliability
- SMT (Surface-Mount Technology) allows previously successful circuitry to be "dropped in" to circuit boards in combination with custom routing to meet new requirements rapidly with high confidence
- SMT is high density and alternate-grade parts are widely stocked, so there is no longer a need to rely on custom, long-lead-time, expensive (and large footprint) 3rd party items
- Touch-free assembly without discrete wires or hand-place parts should be standard, on rigid-flex PCBs which can be made to fold and drop directly into their enclosures
- High confidence, designed-for-test Power Systems rely on "pyramid" testing where checks for each component function are performed at the lowest level, with decreasing visibility as the system is assembled

Planning for change will allow our Electronics to keep up with future Requirements

Can we seamlessly bring on new power generation, switching, and storage technologies as they become available?

- The transitions between Ni-Cd, Ni-H, and Li-Ion Batteries have each led to re-designs of the supporting electronics. Those systems that already had flexible chargers and dischargers were able to adapt quickly to the challenges, and will also be able to handle the Next energy storage generation

- Solar Arrays that are directly tied to batteries create havoc for everyone, as each generation must be custom-designed, laid out, even going so far as to vary the cell size, string length and array layout depending on the operating temperature predictions. Those systems that employ adjustable Array voltage (or peak-power trackers) can be configured on-the-fly as new array technology, cell sizes, and power levels change

- A Regulated, "Standard" distribution Bus Voltage also allows the use of common payload hardware without regard to battery size or power level. Power converter efficiencies now easily reach 95-98% (especially with GaN) so including them helps with flexibility, modularity and robustness via parallel, active-droop channels

Can we "snap together" power systems from modular components without fear of interface compatibility issues?

- The key to rapid configuration and short lead times is standardization of the EPS interfaces between S/A, Battery chargers, Batteries, and Payload

- Standards will allow production of each subsystem at scale to reduce costs and lead time, as well as increase flexibility to adapt for the next Customer

- For example, if the Standard Battery is set at 32V (eight series cells), the S/A can be standardized to always remain higher than 34V to allow a wide step-down range for charging, and the Main Bus can be standardized to 33V so it always remain higher than the Battery at any state of charge

- Once the basic interfaces are defined, vendors can be assured of a market, similar to our 110V "standard" wall outlet and all the bits that team up to provide power to it

Try to "Future-Proof" each block by designing for wide ranges of Voltage and Power

Can we effectively automate testing to include verification of fault-tolerance as well as Voltage, Current & Power ranges?

- Programmable S/A and battery simulator Sources and Electronic Loads will allow the test script to challenge each power block

- Remote re-programming and on-board auto-tuning for Voltage setpoints and current limiters provide agility for variations in S/A input as well as battery State-of-Charge

- Test to the capabilities of the hardware and not just to the current customer Requirements

Employ circuit simulations and thermal imaging to find practical test limits

Thoughts for the Future

- Spacecraft Power Systems enable the entire Mission, so they must be highly reliable, whether or not the Customer (even your boss) wants or needs it

- Designing to component capabilities and real estate budgets is a good way to determine if series / parallel / larger parts should be put in up front.

- The more modular and internally robust each block is, the less needs to be changed when confronting new needs

- In summary, design like it's for your (parent's sibling's, spouse's) car

The more we think up front the less we will have to work to stay off critical path